APPENDIX K-1. ENVIRONMENTAL ANALYSIS FOR RESIDENTIAL WATER HEATERS

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APPENDIX K-1. ENVIRONMENTAL ANALYSIS FOR RESIDENTIAL WATER HEATERS

K-1.1 SUMMARY

The water heater environmental analysis uses a variant of the U.S. DOE/EIA's National Energy Modeling System (NEMS), called NEMS-BRS, plus some exogenous analysis.[a] The environmental analysis is similar to the utility sector analysis described in Chapter 14 of the water heater Technical Support Document. Outputs of the environmental analysis are in a format similar to the results of DOE/EIA's *Annual Energy Outlook 2000* (*AEO2000).*[1]

K-1.2 PURPOSE OF THE ANALYSIS

The environmental analysis is intended to provide information about the effect that new water heater standards would have on pollutants and other emissions, fulfilling the requirement that the environmental effects of all new federal rules be properly quantified and considered. For each of the standard levels, DOE calculated total power sector emissions based on output from NEMS-BRS. The Department also conducted some exogenous analysis to calculate household emissions which are not covered by NEMS-BRS. The environmental analysis considers only two pollutants, nitrogen oxides (NO_x) and sulfur dioxide (SO_2), and one emission, carbon. Because emissions of SO_2 from power plants are capped by clean air legislation, physical emissions of this pollutant from electricity generation will be only minimally affected by possible water heater standards through changes in allowance prices and banking behavior. Therefore, DOE does not consider changes in power sector SO_2 emissions here, although we report household emissions savings. The only form of carbon tracked by NEMS-BRS is carbon dioxide (CO_2), so the carbon discussed in this analysis is only in the form of CO_2, but is reported as mass of elemental carbon, in keeping with standard practice.

K-1.3 ASSUMPTIONS

The environmental analysis uses the same basic assumptions as *AEO2000*, and we modeled the changes resulting from standards as variations of current policy. For example, the emissions characteristics of an electricity generating plant in this environmental assessment are the same as those used in *AEO2000*, although the fuel mix used for generation and the construction program for

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[a] For more information on NEMS, please refer to the U.S. Department of Energy, Energy Information Administration documentation. A useful summary is *National Energy Modeling System: An Overview 2000*, DOE/EIA-0581(2000), March 2000. DOE/EIA approves use of the name NEMS to describe only an official version of the model without any modification to code or data. Because our analysis entails some minor code modifications and the model is run under policy scenarios that are variations on DOE/EIA assumptions, the name NEMS-BRS refers to the model as used here (BRS is DOE's Building Research and Standards office, under whose aegis this work has been performed).

new plants may be slightly different as a result of reduced generation requirements under the standard, which in turn affects pollution results. As with the utility impact analysis in Chapter 14, effects are assumed to be linear in the range of the standards decrements and results are extrapolated.

DOE also performed a sensitivity analysis using the High and Low Economic Growth scenarios of NEMS-BRS. As described in Chapter 14, these scenarios cover a range of macroeconomic growth assumptions. In addition to the differing macroeconomic growth assumptions in NEMS-BRS, the energy savings estimates of the National Energy Savings (NES) model (see Chapter 12) also differ from those implemented in the reference cases.

K-1.4 METHODS

K-1.4.1 Carbon

A detailed carbon module tracks carbon emissions in NEMS-BRS. The carbon module provides good results because it covers all sectors of the economy and their interactions. Because NEMS-BRS tracks carbon emissions based on total energy consumption and produces comprehensive estimates of the benefits of proposed standards, actual household emissions are included and no exogenous analysis is necessary. NEMS itself does not account for potential carbon savings that result from upstream processes as described in the fuel-cycle section below.

Past experience with NEMS carbon results from power generation suggests that marginal emissions estimates are somewhat lower than emissions based on simple forecast average factors for two reasons. First, the marginal fuel displaced by reduced generation as a result of proposed standards tends to be natural gas, which releases less carbon than coal. Second, lowered electricity demand tends to slow down the construction of power generation capacity, thereby slowing improvement in energy conversion efficiency and emissions rates that typically result from deployment of newer technology.

K-1.4.2 Power Sector NO_x

NEMS-BRS reports the two airborne pollutant emissions that have been reported in past analyses, NO_x and SO_2. NO_x results are based on forecasts of compliance with existing legislation and have proven stable and reasonable.

K-1.4.3 Power Sector SO_2

The Clean Air Act Amendments of 1990 set an SO_2 emissions cap on all power generation but permits flexibility among generators through the use of emissions allowances and tradable permits. SO_2 trading tends to imply that physical emissions effects of a standard will be zero because emissions will always be at or near the ceiling. There is virtually no real possible SO_2 environmental benefit from electricity conservation as long as there is enforcement of the emissions ceiling. A slight economic benefit may result only if coal generation falls and the reduced demand for SO_2

emissions allowances lowers the allowance price. Because the effects considered here are too small to deliver reasonable estimates, we do not consider this possibility.

K-1.4.4 Household Emissions

While NEMS-BRS has an algorithm for estimating emissions of NO_x and SO_2 from power generation, it does not estimate household emissions. Because households use natural gas, oil, and LPG, the residential sector also contributes to NO_x and SO_2 emissions. This analysis therefore includes separate estimates of the effect of standards on household NO_x and SO_2 emissions, based on simple emissions factors derived from the literature. Although small, household SO_2 emissions savings are reported because the SO_2 emissions caps do not apply to the residential sector. Appendix K-2 provides a detailed description of the methodology for deriving the emissions factors for residential combustion.

K-1.4.5 Fuel-Cycle Emissions

NEMS-BRS does not account for upstream emissions from energy losses during coal and natural gas production. The upstream processes include the mining of coal or extraction of natural gas, physical preparatory and cleaning processes, and transportation to the power plant. Appendix K-3 shows upstream emissions factors for carbon, SO_2, and NO_x, along with the relative percentage of upstream emissions relative to power plants emissions. The Appendix also provides a detailed description of the methodology used to derive these estimates. Although DOE does not report actual estimates of the effects of standards on upstream emissions, the material in Appendix K-3 provides the reader with a feel for the possible magnitude effects.

K-1.4.6 Interpolation

Because the size of the energy savings from standards are too small to produce stable power sector results in NEMS-BRS, it is necessary to estimate results in the range of the standard levels effects using interpolation. Appendix I of the Technical Support Document describes the interpolation methodology in detail. A series of cases is executed in which the Residential Demand Module's water heater load is reduced for each of the fuel types (electricity, natural gas, LPG, and oil) at incrementally higher savings than the standards levels. Actual standard level savings are then derived from these outputs.

K-1.4.7 Extrapolation

The current time horizon of NEMS-BRS is 2020 (we model an 17-year period, 2004-2020), yet other parts of the appliance energy-efficiency work reach 2030. As described in the utility analysis in Chapter 14, it is not feasible to extend the forecast period of NEMS-BRS for the purposes

of this analysis, nor does EIA have an approved method for extrapolation of many outputs beyond 2020; therefore, all extrapolations beyond 2020 presented here are simple replications of year 2020 results. While these may seem unreasonable in some instances, in this way results are guaranteed to be consistent. As with the *AEO2000* Reference Case in general, the implicit assumption is that the regulatory environment does not change from the current, known situation during the extrapolation period. Only changes that have been announced with date-certain introduction are included in NEMS-BRS. Consistent with this assumption, the household emissions factors used do not change in either the forecast or the extrapolation periods because little compelling evidence of tightening emissions standards for household appliances was found in the research described in Appendix K-2 To emphasize the extrapolated results wherever they appear, they are shaded in grey to distinguish them from actual NEMS-BRS output.

K-1.5 RESULTS

K-1.5.1 Power Sector Emissions

Table K-1.1 shows total power sector carbon and NO_x emissions for each of the four proposed trial standard levels.

The annual carbon emissions reductions range up to 3.1 Mt in 2020. NO_x emissions reductions reach up to 11.8 kt by 2015. Table K-1.2 lists cumulative emissions savings for the power sector over the 17-year period modeled.

Table K-1.1 Power Sector Emissions: Reference Case

	NEMS-BRS Results				Difference from AEO2000 Reference					
	2005	2010	2015	2020	2005	2010	2015	2020	2025	2030
AEO2000 Reference Case									**Extrapolation**	
Carbon (Mt/yr)*,***	645.5	681.0	725.9	757.8						
NO_x (kt/yr)**,***	4,989.5	5,134.7	5,325.2	5,379.6						
Trial Standard Level 1										
Carbon (Mt/yr)	645.5	680.9	725.6	757.5	0.0	-0.1	-0.3	-0.3	-0.3	-0.3
NO_x (kt/yr)	4,989.5	5,133.0	5,321.3	5,378.4	0.0	-1.7	-3.9	-1.2	-1.2	-1.2
Trial Standard Level 2										
Carbon (Mt/yr)	645.3	680.5	724.9	756.6	-0.2	-0.5	-1.0	-1.2	-1.2	-1.2
NO_x (kt/yr)	4,987.7	5,131.5	5,319.5	5,377.5	-1.9	-3.1	-5.7	-2.1	-2.1	-2.1
Trial Standard Level 3										
Carbon (Mt/yr)	645.0	679.6	723.5	754.7	-0.5	-1.4	-2.4	-3.1	-3.1	-3.1
NO_x (kt/yr)	4,986.2	5,127.0	5,313.4	5,371.7	-3.4	-7.6	-11.8	-7.9	-7.9	-7.9
Trial Standard Level 4										
Carbon (Mt/yr)	646.0	682.4	726.8	759.5	0.5	1.4	0.9	1.7	1.7	1.7
NO_x (kt/yr)	4,991.2	5,140.6	5,321.1	5,387.8	1.7	5.9	-4.1	8.2	8.2	8.2

*Comparable to Table A17 of *AEO2000*: Electric Generators
**Comparable to Table A8 of *AEO2000*: Emissions
***All results in metric tons (t), equivalent to 1.1 short tons; Mt = million metric tons, kt = thousand metric tons

Table K-1.2 Cumulative Emissions Reductions Through 2020: Power Sector

	Trial Standard Level			
Emission	**1**	**2**	**3**	**4**
Carbon (Mt)	2.7	11.5	30.1	-19.4
NO_x (kt)	29.2	55.5	133.4	-53.2

We report equivalent results for the Low and High Economic Growth cases in Tables K-1.3 and K-1.4. The outcome of the analysis for each case is shown as both total power sector emissions and deviations from the *AEO2000* result. Generally, the savings for the Low Economic Growth cases are slightly lower for carbon than those reported for the comparable Reference Case standards scenario while the savings for the High Economic Growth cases are slightly higher than those

reported for the Reference Case. The differences between the reference and sensitivity cases are due not only to changes in the macroeconomic assumptions of NEMS-BRS but also to variations in the assumptions used when calculating savings with the NES model.

Table K-1.3 Power Sector Emissions: Low Economic Growth

NEMS-BRS Results					Difference					
	2005	2010	2015	2020	2005	2010	2015	2020	2025	2030
AEO2000 Low Economic Growth					**Difference from AEO2000 Reference Case**				**Extrapolation**	
Carbon (Mt/yr)	633.3	661.6	695.0	715.5	-12.2	-19.4	-30.9	-42.3		
NO_x (kt/yr)	4,907.9	5,016.7	5,161.9	5,234.5	-81.6	-117.9	-163.3	-145.1		
Trial Standard Level 1					**Difference from AEO2000 Low Economic Growth Case**					
Carbon (Mt/yr)	633.3	661.4	694.9	715.3	0.0	-0.2	-0.1	-0.2	-0.2	-0.2
NO_x (kt/yr)	4,907.9	5,014.5	5,160.3	5,233.0	0.0	-2.2	-1.5	-1.5	-1.5	-1.5
Trial Standard Level 2										
Carbon (Mt/yr)	633.1	661.1	694.3	714.4	-0.2	-0.5	-0.7	-1.1	-1.1	-1.1
NO_x (kt/yr)	4,906.7	5,014.2	5,157.8	5,228.9	-1.2	-2.5	-4.0	-5.5	-5.5	-5.5
Trial Standard Level 3										
Carbon (Mt/yr)	632.8	660.2	693.0	712.6	-0.5	-1.4	-2.0	-2.9	-2.9	-2.9
NO_x (kt/yr)	4,904.8	5,009.4	5,152.5	5,222.0	-3.1	-7.3	-9.4	-12.5	-12.5	-12.5
Trial Standard Level 4										
Carbon (Mt/yr)	633.8	662.5	696.6	717.2	0.5	0.9	1.6	1.7	1.7	1.7
NO_x (kt/yr)	4,911.3	5,019.9	5,164.3	5,237.7	3.4	3.2	2.4	3.2	3.2	3.2

Table K-1.4 Power Sector Emissions: High Economic Growth

NEMS-BRS Results					Difference					
	2005	2010	2015	2020	2005	2010	2015	2020	2025	2030
AEO99 High Economic Growth					**Difference from AEO2000 Reference Case**				**Extrapolation**	
Carbon (Mt/yr)	663.4	711.0	765.9	816.6	17.9	30.0	40.0	58.8		
NO_x (kt/yr)	5,098.4	6,316.1	5,452.2	5,461.3	108.9	181.4	127.0	81.6		
Trial Standard Level 1					**Difference from AEO2000 High Economic Growth Case**					
Carbon (Mt/yr)	663.4	711.0	765.6	816.2	0.0	0.0	-0.3	-0.4	-0.4	-0.4
NO_x (kt/yr)	5,098.4	5,315.2	5,449.6	5,466.0	0.0	-0.9	-2.6	4.7	4.7	4.7
Trial Standard Level 2										
Carbon (Mt/yr)	663.3	710.3	764.6	814.8	-0.1	-0.7	-1.3	-1.8	-1.8	-1.8
NO_x (kt/yr)	5,096.9	5,311.2	5,446.8	5,463.4	-1.4	-4.9	-5.4	2.2	2.2	2.2
Trial Standard Level 3										
Carbon (Mt/yr)	662.9	709.2	762.9	812.5	-0.5	-1.8	-3.0	-4.1	-4.1	-4.1
NO_x (kt/yr)	5,095.3	5,305.2	5,441.7	5,459.3	-3.1	-10.9	-10.5	-2.0	-2.0	-2.0
Trial Standard Level 4										
Carbon (Mt/yr)	663.9	712.6	767.6	818.7	0.5	1.6	1.7	2.1	2.1	2.1
NO_x (kt/yr)	5,101.7	5,320.3	5,457.9	5,477.7	3.3	4.2	5.7	16.5	16.5	16.5

K-1.5.2 Residential Sector Emissions

Total household carbon, NO_x, and SO_2 emissions savings are presented in Table K-1.5 for the Reference Case and Tables K-1.6 and K-1.7 for the Low and High Economic Growth cases. These figures represent the sum of residential emissions reductions that result from reduced combustion of natural gas, oil, and LPG due to the trial standard levels. The annual emissions savings in 2020 range from 5.6 to 16.4 Mt/yr for carbon, 6.5 to 29.3 kt/yr for NO_x, and increases of 0.18 to 3.4 kt/yr for SO_2. These savings are in addition to the power sector savings reported above.

Table K-1.5 Change in Household Emissions: Reference Case

	2005	2010	2015	2020	2025	2030
Trial Standard Level 1					**Extrapolation**	
Carbon (Mt/yr)	-4.48	-5.03	-5.40	-5.58	-5.58	-5.58
NO_x (kt)	-0.96	-3.53	-5.54	-6.55	-6.55	-6.55
SO_2 (kt/yr)	0.02	0.06	0.11	0.18	0.18	0.18
Trial Standard Level 2						
Carbon (Mt/yr)	-3.33	-3.98	-4.43	-4.62	-4.62	-4.62
NO_x (kt/yr)	-1.00	-3.72	-5.78	-6.68	-6.68	-6.68
SO_2 (kt/yr)	0.07	0.23	0.41	0.60	0.60	0.60
Trial Standard Level 3						
Carbon (Mt/yr)	-3.18	-3.42	-3.50	-3.35	-3.35	-3.35
NO_x (kt/yr)	-0.50	-1.93	-2.81	-2.66	-2.66	-2.66
SO_2 (kt/yr)	0.08	0.27	0.47	0.68	0.68	0.68
Trial Standard Level 4						
Carbon (Mt/yr)	-9.65	-12.62	-14.96	-16.43	-16.43	-16.43
NO_x (kt/yr)	-4.14	-15.25	-24.15	-29.27	-29.27	-29.27
SO_2 (kt/yr)	0.37	1.29	2.28	3.42	3.42	3.42

Table K-1.6 Change in Household Emissions: Low Economic Growth Case

	2005	2010	2015	2020	2025	2030
Trial Standard Level 1					**Extrapolation**	
Carbon (Mt/yr)	-4.46	-4.99	-5.35	-5.50	-5.50	-5.50
NO_x (kt/yr)	-0.94	-3.45	-5.36	-6.27	-6.27	-6.27
SO_2 (kt/yr)	0.02	0.05	0.09	0.15	0.15	0.15
Trial Standard Level 2						
Carbon (Mt/yr)	-3.32	-3.96	-4.40	-4.57	-4.57	-4.57
NO_x (kt/yr)	-0.99	-3.66	-5.64	-6.47	-6.47	-6.47
SO_2 (kt/yr)	0.06	0.21	0.36	0.52	0.52	0.52
Trial Standard Level 3						
Carbon (Mt/yr)	-3.17	-3.45	-3.56	-3.44	-3.44	-3.44
NO_x (kt/yr)	-0.52	-2.00	-2.95	-2.89	-2.89	-2.89
SO_2 (kt/yr)	0.07	0.24	0.41	0.59	0.59	0.59
Trial Standard Level 4						
Carbon (Mt/yr)	-9.58	-12.43	-14.63	-15.88	-15.88	-15.88
NO_x (kt/yr)	-4.03	-14.74	-23.10	-27.61	-27.61	-27.61
SO_2 (kt/yr)	0.34	1.14	1.98	2.93	2.93	2.93

Table K-1.7 Change in Household Emissions: High Economic Growth Case

	2005	2010	2015	2020	2025	2030
Trial Standard Level 1					**Extrapolation**	
Carbon (Mt/yr)	-4.49	-5.07	-5.45	-5.67	-5.67	-5.67
NO_x (kt/yr)	-0.98	-3.64	-5.71	-6.79	-6.79	-6.79
SO_2 (kt/yr)	0.02	0.07	0.12	0.20	0.20	0.20
Trial Standard Level 2						
Carbon (Mt/yr)	-3.34	-4.01	-4.48	-4.70	-4.70	-4.70
NO_x (kt/yr)	-1.02	-3.81	-5.93	-6.87	-6.87	-6.87
SO_2 (kt/yr)	0.08	0.26	0.44	0.64	0.64	0.64
Trial Standard Level 3						
Carbon (Mt/yr)	-3.18	-3.41	-3.49	-3.36	-3.36	-3.36
NO_x (kt/yr)	-0.48	-1.87	-2.75	-2.57	-2.57	-2.57
SO_2 (kt/yr)	0.09	0.30	0.50	0.73	0.73	0.73
Trial Standard Level 4						
Carbon (Mt/yr)	-9.69	-12.83	-15.30	-16.92	-16.92	-16.92
NO_x (kt/yr)	-4.30	-15.86	-25.16	-30.68	-30.68	-30.68
SO_2 (kt/yr)	0.41	1.45	2.52	3.76	3.76	3.76

Table K-1.8 shows cumulative emissions savings for households over the 17-year period modeled in the Reference Case.

Table K-1.8 Cumulative Emissions Reductions Through 2020: Households

	Trial Standard Level			
Emission	**1**	**2**	**3**	**4**
Carbon (Mt)	86.9	69.3	57.5	225.7
NO_x (kt)	68.9	71.7	34.0	301.4
SO_2 (kt)	-1.5	-5.3	-6.0	-29.3

K-1.5.3 Power and Residential Sector Emissions

Cumulative emissions savings for the power sector and households together (excluding upstream emissions) over the 17-year period modeled are presented in Table K-1.9 below.

Table K-1.9 Cumulative Emissions Reductions Through 2020: Power Sector and Households

	Trial Standard Level			
Emission	**1**	**2**	**3**	**4**
Carbon (Mt)	89.6	80.8	87.6	206.3
NO_x (kt)	98.2	127.2	167.4	248.2
SO_2 (kt)	-1.4*	-5.2*	-6.0*	-29.3*

*Results include only household emissions reductions because the power sector emissions cap implies that savings from electricity generation will be negligible.

Cumulative emissions savings for the combined power and residential sectors (excluding upstream emissions) with the forecast extended through 2030 are shown in Table K-1.10.

Table K-1.10 Cumulative Emissions Reductions Through 2030: Power Sector and Households

	Trial Standard Level			
Emission	**1**	**2**	**3**	**4**
Carbon (Mt)	148.5	139.1	152.0	353.6
NO_x (kt)	175.4	214.9	273.2	458.8
SO_2 (kt)	-3.2*	-11.3*	-12.8*	-63.5*

* Results include only household emissions reductions because the power sector emissions cap implies that savings from electricity generation will be negligible.

K-1.5.4 Fuel-Cycle Emissions

The effects of standards on upstream emissions are not reported here. Please refer to Appendix K-3 for a general description of the possible magnitude of these effects.

REFERENCE

1. U.S. Department of Energy-Energy Information Administration, *Annual Energy Outlook 2000 with Projections to 2020,* December, 1999. Washington, DC. Report No. DOE/EIA-0383(2000). <http://www.eia.doe.gov/oiaf/aeo/index.html>